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Address to:

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney's Docket No. SONY-T0457First Named Inventor KAZUHIKO UEDA

UTILITY PATENT APPLICATION TRANSMITTAL
(under 37 CFR 1.53(b))

SIR:

Transmitted herewith for filing is the patent application entitled:
IMAGE PROCESSOR AND IMAGE PROCESSING METHOD

CERTIFICATION UNDER 37 CFR § 1.10

I hereby certify that this New Application and the documents referred to as enclosed herein are being deposited with the United States Postal Service on this date April 13, 2000, in an envelope bearing "Express Mail Post Office To Addressee" Mailing Label Number EL254110044US addressed to: Box Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

John Lyddan

(Name of person mailing paper)

John Lyddan
(Signature)

Enclosed are:

1. ☒ Transmittal Form (two copies required)
2. The papers required for filing date under CFR § 1.53(b):
 - i. 35 Pages of specification (including claims and abstract);
 - ii. 13 Sheets of drawings.
 - ☐ formal
 - ☒ informal
3. Declaration or oath
 - a. ☒ (unsigned)
4. ☐ Microfiche Computer Program (Appendix, see 37 CFR 1.96)
5. ☐ Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
 - i. ☐ Computer Readable Copy
 - ii. ☐ Paper Copy (identical to computer copy)
 - iii. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

6. ☐ An assignment of the invention to SONY CORPORATION is attached (including Form PTO-1595).
 - i. ☐ 37 CFR 3.73(b) Statement (when there is an assignee)
7. ☒ Power of Attorney (unsigned)
8. ☐ An Information Disclosure Statement (IDS) is enclosed, including a PTO-1449 and copies of ☐ references.
9. ☐ Preliminary Amendment.
10. ☒ Return Receipt Postcard (MPEP 503 -- should be specifically itemized)
11. ☐ Other

12. FOREIGN PRIORITY

[x] Priority of application no. P11-109172 filed on April 16, 1999 in Japan is claimed under 35 USC 119.

The certified copy of the priority application:

 x is filed herewith; or
 _ has been filed in prior application no. _ filed on _ , or
 _ will be provided.

English Translation Document (if applicable)

13. FEE CALCULATION

a. Amendment changing number of claims or deleting multiple dependencies is enclosed.

CLAIMS AS FILED

	Number Filed	Number Extra	Rate	Basic Fee (\$690)
Total Claims	30 - 20	* 10	x \$18.00	\$180.00
Independent Claims	2 - 3	* 0	x \$78.00	\$.00
— Multiple dependent claim(s), if any			\$260.00	\$.00

*If less than zero, enter "0".

Filing Fee Calculation \$870.00

50% Filing Fee Reduction (if applicable) \$.00

14. Small Entity Status

- a. ☐ A small entity statement is enclosed.
- b. ☐ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
- c. ☐ is no longer claimed.

15. Other Fees

— Recording Assignment [\$40.00]	\$.00
— Other fees	
Specify _____	\$.00
Total Fees Enclosed	\$870.00

16. Payment of Fees

- x Check(s) in the amount of \$ 870.00 enclosed.
 Charge Account No. 12-1420 in the amount of \$.
A duplicate of this transmittal is attached.

17. All correspondence regarding this application should be forwarded to the undersigned attorney:

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18. Authorization to Charge Additional Fees

- X The Commissioner is hereby authorized to charge any additional fees (or credit any overpayment) associated with this communication and which may be required under 37 CFR § 1.16 or § 1.17 to Account No. 12-1420. **A duplicate of this transmittal is attached.**

LIMBACH & LIMBACH L.L.P.

April 13, 2000
(Date)

Attorney Docket No. SONY-T0457
[S00P0457US00]

By: Charles P. Sammut
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IMAGE PROCESSOR AND IMAGE PROCESSING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an image processor and image processing method which may be adapted, for example, to an image processor such as television receiver, video tape recorder, television camera and printer or the like. The present invention judges a domain to which image data belongs, for example, with reference to low frequency element of a pixel value and compensates for signal level of image data based on the result of judgment in order to compensate for gradation by effectively avoiding deterioration of partial contrast.

Description of the Related Art

In an image processor such as television camera or the like of the related art, an output signal is provided after compensation for gradation of image data which is obtained through an image input means such as an image sensing means.

Fig. 15 is a characteristic curve illustrating an input/output characteristic of a signal processing circuit adapted to such gradation compensating process. A signal processing circuit of this type reduces the gain when an input level 1 exceeds the predetermined reference level 1k. Thereby, the signal processing circuit of this type outputs a suppressed signal level when the input level becomes higher than the reference level 1k. In this case, gradation is

compensated by sacrificing contrast of the part in the higher signal level.

In the characteristic curve of Fig. 15, the horizontal axis shows a pixel value 1 indicating an input level of image data, while the vertical axis shows a pixel value $T(1)$ indicating an output level of image data. Moreover, L_{\max} shows the maximum level which each pixel of input/output image can take. In the following explanation, a function indicating an input/output relationship as indicated in the characteristic curve is called a level conversion function.

Fig. 16 is a characteristic curve showing the input/output characteristic of a signal processing circuit of the same type. The signal processing circuit based on this level conversion function reduces the gain when the input level 1 is the first reference level 1s or less and the second reference level 1b or more. Thereby, this signal processing circuit is caused to compensate for gradation by sacrificing contrast at the part of low signal level and high signal level.

Meanwhile, in the image processing utilizing a computer, gradation is compensated, for example, by histogram equalization.

In this histogram equalization method, the level conversion function is adaptively changed depending on frequency distribution of pixel value if an input image and moreover gradation is compensated by reducing gradation of the part having lower frequency distribution of pixel value.

Namely, as illustrated in Fig. 17, in the process of

histogram equalization, accumulated frequency distribution $C(l)$ by the arithmetic operation of the following formula is detected based on the frequency distribution $H(l)$ which is collection of the number of pixels with reference to the pixel value l of the input image.

$$C(l) = \sum_{k=0}^l H(k) \quad \dots (1)$$

In the histogram equalization process, the level conversion function $T(l)$ is defined by normalizing the accumulated frequency distribution $C(l)$ detected as explained above with the following formula and the signal level of input image is compensated depending on this level conversion function $T(l)$. Here, F_{\max} is the final value of the accumulated frequency distribution $C(l)$ and L_{\max} is the maximum value of the input/output level.

$$T(l) = \frac{C(l)}{F_{\max}} \times L_{\max} \quad \dots (2)$$

Such process to compensate for gradation is executed as required for suppression of dynamic range even when image data is transmitted to the transmission line and when image data is displayed on a display unit or when image data is stored in a storage apparatus.

In the gradation compensating process by the method of the related art, total gradation is compensated by sacrificing contrast of a certain part in order to avoid generation of unnatural image and to convert the level with the input/output function having the monotonous increasing

characteristic even in any kind of method.

Therefore, the method of the related art has a problem that contrast is partially lowered in the processed image.

SUMMARY OF THE INVENTION

The present invention has been proposed considering the problems explained above and therefore it is an object of the present invention to provide an image processor and an image processing method which can compensate for gradation by effectively avoiding drop of partial contrast.

In view of solving the problems, in the image processor and image processing method of the present invention, a domain to which image data belongs is judged, a compensation coefficient for compensating for pixel value of image data is generated based on the result of judgment and a pixel value of image data is compensated depending on such compensation coefficient.

A domain to which image data belongs is judged, a compensation coefficient for compensating for pixel value of image data is generated and a pixel value of image data is compensated depending on such compensation coefficient. Thereby, the pixel value is compensated with the same coefficient in the same domain to maintain relationship of pixel values within the domain and such relationship of pixel values may also be inverted among the pixels belonging to different domains. Accordingly, it is now possible to compensate for total gradation by avoiding partial

deterioration of contrast.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram illustrating a television camera as a first embodiment of the present invention.

Figs. 2A to 2C illustrate characteristic curves for explaining the process of image sensing by the television camera.

Fig. 3 is a schematic diagram illustrating arrangement of pixel values in the television camera of Fig. 1.

Fig. 4 illustrates characteristic curve for explaining the contrast compensation coefficient $g(I, j)$.

Figs. 5A to 5D illustrate signal waveforms for explaining the process of a gradation compensating circuit in the television camera of Fig. 1.

Figs. 6A to 6D illustrate signal waveforms for explaining the process of a gradation compensating circuit in the input level which is different from that of Figs. 5A to 5D.

Fig. 7 is a block diagram illustrating a gradation compensating circuit adapted to the television camera in relation to the second embodiment of the present invention.

Fig. 8 is a block diagram illustrating a gradation compensating circuit adapted to the television camera in relation to the third embodiment of the present invention.

Fig. 9 is a block diagram illustrating a gradation compensating circuit adapted to the television camera in

relation to the fourth embodiment of the present invention.

Figs. 10A and 10B illustrate signal waveforms for explaining operations of a gradation compensating circuit of Fig. 9.

Fig. 11 is a block diagram illustrating a gradation compensating circuit adapted to the television camera in relation to the fifth embodiment of the present invention.

Fig. 12 illustrates a characteristic curve for explaining a level converting function adapted to a gradation compensating circuit in relation to the other embodiment.

Fig. 13 is a plan view for explaining a color filter.

Fig. 14 illustrates signal waveforms showing the result of image sensing when the color filter of Fig. 13 is used.

Fig. 15 illustrates a characteristic curve for explaining a level converting function adapted to the dynamic range suppressing process in the related art.

Fig. 16 illustrates a characteristic curve for explaining a level converting function adapted to the dynamic range suppressing process in the other embodiment different from that of Fig. 15.

Fig. 17 illustrates characteristic curves for explaining the histogram equalization process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will be explained in detail with reference to the accompanying drawings.

(1) First Embodiment

(1-1) Structure of the first embodiment

Fig. 1 is a block diagram illustrating a television camera in relation to the first embodiment of the present invention. In this television camera 1, a CCD solid-state image sensing device (CCD) 2 outputs an image sensing result when it is driven by a timing generator (TG) 3. In this case, the CCD solid-state image sensing device 2 obtains an image sensing device in the period of 1/60 (sec) depending on the charge accumulation time preset by a user and then outputs the image sensing result as the image sensing result VN by the ordinary exposing process. Moreover, the CCD solid-state image sensing device 2 obtains the image sensing result during the charge accumulation time which is shorter than that by the ordinary exposing process in the vertical blanking period of the image sensing result VN by such ordinary exposing process and then outputs such image sensing result as the image sensing result of short term exposing process.

Thereby, as illustrated in Fig. 2, the CCD solid-state image sensing device 2 outputs, when amount of incident light is higher than the predetermined amount, a set of the image sensing result VN (Fig. 2A) by the ordinary exposing process in which the output level is saturated and the image sensing result VS (Fig. 2B) of the short term exposing process in which an output level is not saturated during the shorter charge accumulation time.

A memory 4N inputs the image sensing result VN

(converted to the color signals of red, blue and green) by such ordinary exposing process through a correlated double sampling circuit, a fault compensating circuit, a matrix arithmetic circuit and an analog/digital converting circuit or the like not illustrated and then outputs the image sensing result VN by the ordinary exposing process after this result is temporarily stored.

In the same manner, a memory 4S inputs the image sensing result VS by this short term exposing process through a correlated double sampling circuit, a fault compensating circuit, a matrix arithmetic circuit and an analog/digital converting circuit or the like not illustrates and then outputs the image sensing result VS by this short term exposing process after it is temporarily stored.

An adding circuit 5 adds the image sensing result VN by the ordinary exposing process stored in the memory 4N and the image sensing result VS by the short term exposing process stored in the memory 4S to output the image sensing result VT of wide dynamic range and sufficient pixel value, while a level compensating circuit 6 outputs, through compensation, the pixel value of the image sensing result VS by the short term exposing output from the memory 4S in view of obtaining sufficient linearity for practical use in the image sensing result VT by this adding circuit 5.

Thereby, in the television camera 1, the image sensing result VT (Fig. 2C) of remarkably wider dynamic range in comparison with that in the related art can be generated.

The gradation compensating circuit 8 outputs, through compensation, gradation of the image sensing result VT by compensating for the pixel value of this image sensing result VT. A subsequent signal processing circuit 9 executes various signal processes required for the television camera and then outputs the image sensing result to external devices. In this case, the dynamic range of image sensing result is suppressed by uniformly suppressing the pixel value of the image sensing result corresponding to the output device.

In this process, the gradation compensating circuit 8 preliminarily executes the arithmetic process indicated by the following formula to generate a luminance signal Y from the image sensing result VT by the color signals R, G, B and outputs, through compensation, the gradation of color signals R, G, B with reference to the luminance signal Y.

$$Y=0.3R+0.59G+0.11B \quad \cdots (3)$$

Here, in the gradation compensating circuit 8, a domain judging filter 10 judges a domain to which image data which is a luminance signal Y belongs and outputs the result of judgment. In this case, the domain judging filter 10 detects a mean luminance level which is the mean value of pixel values as the characteristic amount indicating the characteristic of the neighboring predetermined range of image data to judge to which domain of the mean luminance level the image data belongs and then outputs the mean value which is the mean luminance level as the result of judgment.

Namely, the domain judging filter 10 is a two-dimensional low-pass filter which detects a low frequency element $r(i, j)$ represented by the following arithmetic formula for the pixel value $x(i, j)$ of the luminance signal Y in the image sensing result VT sequentially input in the sequence of the raster scanning and also outputs the low frequency element $r(i, j)$ as the result of judgment.

$$r(i, j) = \frac{\sum_{dj=-N/2}^{N/2} \sum_{di=-M/2}^{M/2} x(i+di, j+dj)}{M \times N} \dots\dots (4)$$

N, M in the formula (3) are constant indicating a size of neighboring domain to calculate the mean value. Moreover, as illustrated in Fig. 3, in this embodiment, regarding the image sensing result VT input in the sequence of raster scanning, the horizontal direction is indicated by the subscript of code i , while the vertical direction by the subscript of code j . Therefore, the domain judging filter 10 can extract the domain in which the pixel values are comparatively flat by eliminating the more minute structure than that in the image of the image sensing result VT . Here, the domain judging filter 10 preferably has a comparatively narrow frequency band because of the purpose to execute the process explained above.

A coefficient calculating circuit 11 generates, for example, a contrast compensation coefficient $g(i, j)$ with a coefficient calculating function G illustrated in Fig. 4 depending on the signal level of the low frequency element $r(i, j)$. Here, the coefficient calculating function G can

be obtained, for example, through the arithmetic process of the level converting function $T(l)$ conforming to the following formula explained with reference to Fig. 15.

$$G(l) = \frac{T(l)}{1} \quad \text{..... (5)}$$

Thereby, the coefficient calculating circuit 11 generates and inputs the contrast compensation coefficient $g(i, j)$ by the arithmetic process of the following formula, outputs the contrast compensation coefficient $g(i, j)$ by the constant value g_{\max} of value 1 or larger for the domain in which the signal level of the low frequency element $r(i, j)$ as the input level and also outputs the contrast compensation coefficient $g(i, j)$ which gradually comes close to the value g_{\min} depending on the signal level of the low frequency element $r(i, j)$ for the domain in which the signal level is the reference level lk or higher.

$$g(i, j) = G(r(i, j)) \quad \text{..... (6)}$$

A multiplying circuit 12 outputs, through compensation, the signal level of the image sensing result TV with the contrast compensation coefficient $g(i, j)$ by multiplying (in this case, the process for each color signal) the contrast compensation coefficient $g(i, j)$ generated as explained above and the pixel value $x(i, j)$ of the corresponding image sensing result VT .

(1-2) Operations of the first embodiment

In above structure, in the television camera 1 (Fig.

1), the image sensing result VN (Fig. 2A) by the ordinary exposing process during the charge accumulation period set by a user and the image sensing result VS (Fig. 2B) by the short term exposing during the short charge accumulation period are alternately output from the CDD solid-stage image sensing device 2 and these image sensing results VN and VS are respectively stored in the memories 4N and 4S. In the television camera 1, these two image sensing results VN and VS are combined by the level compensating circuit 6 and adding circuit 5. Thereby, the image sensing result VT (Fig. 2C) having remarkably wider dynamic range than that of the related art can be generated.

In this image sensing result VT, the luminance signal Y is generated, a means value of pixel values which is the characteristic amount indicating the characteristic of neighboring predetermined range of the input image data is detected in the domain judging filter 10 of the gradation compensating circuit 8. Thereby, result of judgment indicating the domain to which the input image data belong can be generated. In more practical, the domain judging filter 10 detects the low frequency element $r(i, j)$ which is a means value of the pixel values to thereby eliminate a minute structure in the image and also extracts the domain in which the pixel values are comparatively flat. Moreover, this low frequency element $r(i, j)$ is output as the result of judgment.

In the image sensing result VT, the contrast

compensation coefficient $g(i, j)$ is generated depending on the signal level of this low frequency element $r(i, j)$ by the subsequent coefficient calculating circuit 11, the pixel value is compensated in the multiplying circuit 12 by this contact compensation coefficient $g(i, j)$. Thereby, the pixel value is compensated by the gain depending on each domain with reference to the low frequency element $r(i, j)$ and is then output.

Therefore, in the image sensing result VT, the pixel value is compensated by the equal gain in the domains where the signal level of the low frequency element $r(i, j)$ is equal but the pixel value may be approximated depending on the setting of the level converting function $T(l)$ in the domains where the signal levels of the low frequency element $r(i, j)$ are different. Moreover, in some cases, the relationship among the small and large pixel values may be inverted. Thereby, the contrast in each domain can naturally be increased for the total gradation and total gradation can also be compensated by effectively avoiding deterioration of partial contrast.

Namely, as illustrated in Figs. 5A to 5D, the pixel value $x(i, j)$ of the image sensing result VT pulsates depending on the frequency higher than the cutoff frequency of the low-pass filter 10. Moreover, when the DC level of the pixel value $x(i, j)$ rises suddenly (Fig. 5B) and change of the low frequency element $r(i, j)$ corresponding to sudden change of DC level rides over the point of inflexion of the

coefficient calculation function $G(l)$, the contrast is suppressed at the part where the pixel value $x(i, j)$ is large, depending on the level converting function of the related art explained with reference to Fig. 15 (Fig. 15C).

However, according to this embodiment, before and after the signal level of low frequency element $r(i, j)$ suddenly rises, the pixel value $x(i, j)$ is compensated by the gain depending on the signal level of such low frequency element $r(i, j)$ and the signal level can be compensated by setting the coefficient calculating function $G(l)$. In this case, at the part where the pixel value $x(i, j)$ is small, the pixel value $x(i, j)$ is compensated by the gain g_{\max} based on the mean level 12 of the peak value 13 and bottom value 11 and thereby the contrast which is identical to that in the related art can be obtained for the low level domains (Fig. 5D).

On the other hand, in the high level side, the pixel value $x(i, j)$ is compensated by the gain g_5 based on the mean level 15 of the peak value 16 and bottom value 14. In this case, since the pixel value is compensated by the gain having uniform peak value 16 and bottom value 14, the signal is amplified by this gain g_5 in the contrast between the peak value 16 and bottom value 14.

Accordingly, in this embodiment, gradation is never changed to a large extent from the macroscopic point of view but pulsating due to the image sensing result VT as the input image can be expanded from the microscopic point of view.

Moreover, as illustrated in Figs. 6A to 6D, in the same

manner, the pixel value $x(i, j)$ pulsates and DC level rises suddenly (Fig. 6B). When pulsating of the pixel value $x(i, j)$ is deviated to the high level side from the point of inflexion of the coefficient calculating function $G(l)$ (Fig. 5B), the contrast is suppressed in all pixel values $x(i, j)$ depending on the level converting function of the related art explained with reference to Fig. 15 (Fig. 6C).

However, in this case, the pixel value is also compensated by the gains g_2 and g_5 corresponding to the mean value levels 12 and 15 in the low level and high level sides and the gradation is never changed to a large extent from the macroscopic point of view but large pulsating due to the image sensing result VT as the input image can be expanded from the microscopic point of view.

(1-3) Effect of the first embodiment

According to above structure, the domain to which the image data belongs is judged, the pixel values may be approximated as required among the pixels belonging to different domains while the relationship of small and large pixel values are maintained by the equal coefficient within the same domain by generating the compensation coefficient for compensating pixel value of image data based on the result of judgment and also compensating the pixel value of image data depending on the compensation coefficient and moreover such relationship can also be inverted in the extreme case. Thereby, the contrast in each domain can be expanded in the predetermined level range and total gradation can be

compensated by avoiding drop of the partial contrast.

Moreover, in this case, total gradation can be compensated by avoiding drop of partial contrast with a simplified structure by utilizing the low frequency element by the low-pass filter is used as the characteristic amount to compensate for the pixel value with reference to this low frequency element.

(2) Second Embodiment

Fig. 7 is a block diagram illustrating the gradation compensating circuit adapted to the television camera in relation to the second embodiment of the present invention. This gradation compensating circuit 28 is adapted in place of the gradation compensating circuit 8 explained with reference to Fig. 1.

Here, a quantizing circuit 29 reduces the number of bits and then output it by quantizing the pixel value of the luminance signal Y forming the image sensing result VT. In this embodiment, the quantizing circuit 29 executes the arithmetic process of the following formula in the preset quantizing step Q for the pixel value x (i, j) and thereby outputs the pixel value x' (i, j) by the linear quantizing process of the pixel value x (i, j). Here, int(a) is a function to truncate the fraction part after the decimal point of a.

$$x' (i, j) = \text{int} \left(\frac{x}{Q} + 0.5 \right) \quad \dots (7)$$

A domain judging filter 30 is formed in the same

structure as the domain judging filter 10 of the first embodiment, except for the point that the number of bits is different.

A look-up table (LUT) 31 forms a coefficient calculating circuit of the first embodiment and outputs a compensation coefficient $g(i, j)$ using, as the address, the low frequency element $r(i, j)$ output from the domain judging filter 30. Thereby, the look-up table 31 stores the compensated coefficient LUT (i) indicated by the following formula in the i-th address.

$$\text{LUT}(i) = G(i \times Q) \quad \dots (8)$$

According to the above structure, the effect similar to that of the first embodiment can be obtained even by previously quantizing the pixel value. Moreover, the total processes can as much simplified by generating the compensation coefficient with the look-up table. In addition, preceding quantizing also enables simplification of the structure of domain judging filter and also reduces in size the look-up table.

(3) Third Embodiment

Fig. 8 is a block diagram illustrating a gradation compensating circuit adapted to the television camera in relation to the third embodiment of the present invention. This gradation compensating circuit 38 is adapted in place of the gradation compensating circuit 28 explained with reference to Fig. 7 and the look-up table 41 and compensating

circuit 42 are arranged in place of the look-up table 31 of this gradation compensating circuit 28.

Here, the look-up table 41 has addresses which are less than the number of levels which the output value $r(i, j)$ of the domain judging filter 30 can take and outputs the two addresses $\text{addr0}(i, j)$ and $\text{addr1}(i, j)$ and compensation coefficients $g0(i, j)$, $g1(i, j)$ expressed by the following formula through the access in which the predetermine lower bits of the output value $r(i, j)$ is omitted. Here, the look-up table 41 generates and outputs the addresses $\text{addr0}(i, j)$ and $\text{addr1}(i, j)$ by outputting the output value $r(i, j)$ of the domain judging filter 30 through omission of the lower bits for the address $\text{addr0}(i, j)$ and adding the bit of logic 1 to the least significant bit of the address $\text{addr0}(i, j)$ for the address $\text{addr1}(i, j)$. Here, R_{\max} is the maximum value which the output value $x(I, j)$ of the domain judging filter 30 can take, while R'_{\max} is the maximum value which the address of look-up table 41 can take.

$$\text{addr0}(i, j) = \text{int} \left(\frac{r(i, j)}{R_{\max}} \times R'_{\max} \right)$$

$$\text{addr1}(i, j) = \text{addr0}(i, j) + 1 \quad \dots\dots (9)$$

An interpolating circuit 42 executes the interpolating arithmetic process of the following formula using the addresses $\text{addr0}(i, j)$, $\text{addr1}(i, j)$, compensation coefficients $g0(i, j)$, $g1(i, j)$ input from the look-up table 41 and then outputs the interpolation result as the compensation coefficient $g(i, j)$.

$$g(i, j) = \frac{r'(i, j) - \text{addr0}(i, j)}{\text{addr1}(i, j) - \text{addr0}(i, j)} \times (g1(i, j) - g0(i, j)) + g0(i, j)$$

$$r'(i, j) = \frac{r(i, j)}{R_{\max}} \times R'_{\max} \quad \dots (10)$$

According to the structure illustrated in Fig. 8, the compensation coefficient of which value changes smoothly can be generated using the small-scale look-up table and gradation can also be compensated with as much higher accuracy by generating the compensation coefficient through the interpolation calculating process.

(4) Fourth Embodiment

Fig. 9 is a block diagram illustrating the gradation compensating circuit adapted to the television camera in relation to the fourth embodiment of the present invention. This gradation compensating circuit 48 is adapted in place of the gradation compensating circuit 8 explained with reference to Fig. 1.

In this gradation compensating circuit 48, the domain judging filter 50 is composed of a low-pass filter 50A which outputs the results of judgment $r0(i, j)$, $r1(i, j)$, $r2(i, j)$, ..., $rN-1(i, j)$ of the domains to which the input image data of different resolutions and the signal combining circuit 50B which generates the result of judgment $r(i, j)$ which is the combining signal based on the results of judgment $r0(i, j)$, $r1(i, j)$, $r2(i, j)$, ..., $rN-1(i, j)$ in different resolutions.

The low-pass filter 50A is composed of low-pass filters (LPF) F0, F1, F2, ..., FN - 1 of different passing frequency bandwidth and inputs the pixel value x (I, j) of the luminance signal Y generated from the image sensing result VT to each low-pass filter (LPF) F0, F1, F2, ..., FN - 1 and outputs the corresponding low frequency elements as the result of judgment r0 (i, j), r1 (i, j), r2 (i, j), ..., rN - 1 (i, j).

The signal combining circuit 50B respectively weights the results of judgment r0 (i, j), r1 (i, j), r2 (i, j), ..., rN - 1 (i, j) in the multiplying circuits M0, M1, M2, ..., MN - 1 and thereafter adds these results in the adding circuit 53 and thereby generates and outputs the result of judgment r(i, j) which is a combining signal. In this case, each weighting coefficient w0, w1, w2, ..., wN - 1 in the multiplying circuit M0, M1, M2, ..., MN - 1 is preset to satisfy the relationship of the following formula.

$$\sum_{k=0}^{N-1} w_k = 1 \quad \text{..... (11)}$$

Therefore, in this embodiment, the contour in the image sensing result VT is never emphasized irregularly by the setting of the weighting coefficient w0, w1, w2, ..., wN - 1.

Namely, as illustrated in Figs. 10A and 10B, when the pixel value x (i, j) changes rapidly (Fig. 10A), the signal level changes to alleviate such rapid change of pixel value in the low frequency element r (i, j). If the compensation

coefficient $g(i, j)$ is only generated by the output signal of the low-pass filter as in the case of the embodiment 1 while the signal level of the low frequency element $r(i, j)$ is deviated to the high level side from the point of inflexion explained above in regard to Fig. 4, the pixel value is amplified by large gain immediately before the pixel value $x(i, j)$ changes rapidly, the pixel value is amplified by small gain immediately after the pixel value $x(i, j)$ changes rapidly, and thereby the output value $y(i, j)$ of which contour is emphasized irregularly can then be obtained (Fig. 10B).

In this case, regarding such contour, emphasis of irregular contour can be reduced by compensating the pixel value with almost uniform gain.

Therefore, in this embodiment, the effect similar to that of the first embodiment can be obtained by effectively avoiding emphasis of irregular contour through generation of the compensation coefficient with the low frequency element of a plurality of systems.

According to the structure of Fig. 9, the effect similar to that of the first embodiment can be obtained by effectively avoiding emphasis of irregular contour through generation of the compensation coefficient with the low frequency element of a plurality of systems.

(5) Fifth Embodiment

Fig. 11 is a block diagram illustrating the gradation compensating circuit adapted to the television camera in relation to the fifth embodiment of the present invention.

This gradation compensating circuit 58 is adapted in place of the gradation compensating circuit 8 of Fig. 1.

In this gradation compensating circuit 58, the domain judging filter 60 outputs the results of judgment $r_0(i, j)$, $r_1(i, j)$, $r_2(i, j)$, ..., $r_{N-1}(i, j)$ of different resolutions. Namely, the domain judging filter 60 is respectively composed of low-pass filters (LPF) F_0 , F_1 , F_2 , ..., F_{N-1} of different passing frequency bandwidths and each low-pass filter (LPF) F_0 , F_1 , F_2 , ..., F_{N-1} inputs the pixel value $x(i, j)$ and outputs the corresponding low frequency element as the results of judgment $r_0(i, j)$, $r_1(i, j)$, $r_2(i, j)$, ..., $r_{N-1}(i, j)$.

The coefficient calculating circuit 61 is composed of a coefficient generating circuit 61A which generates the corresponding compensation coefficients $g_0(i, j)$, $g_1(i, j)$, $g_2(i, j)$, ..., $g_{N-1}(i, j)$ from the results of judgment $r_0(i, j)$, $r_1(i, j)$, $r_2(i, j)$, ..., $r_{N-1}(i, j)$ and the coefficient combining circuit 61B which generates a compensation coefficient $g(i, j)$ by combining these compensation coefficients $g_0(i, j)$, $g_1(i, j)$, $g_2(i, j)$, ..., $g_{N-1}(i, j)$.

Of these circuits, the coefficient generating circuit 61A is composed of the coefficient calculating circuits L_0 , L_1 , L_2 , ..., L_{N-1} which generate the corresponding compensation coefficients $g_0(i, j)$, $g_1(i, j)$, $g_2(i, j)$, ..., $g_{N-1}(i, j)$ from the results of judgment $r_0(i, j)$, $r_1(i, j)$, $r_2(i, j)$, ..., $r_{N-1}(i, j)$ respectively based on the

predetermined coefficient calculating function G_k ($k = 0, 1, 2, \dots, N - 1$).

Meanwhile, the coefficient combining circuit 61B respectively weights the compensation coefficients $g_0(i, j)$, $g_1(i, j)$, $g_2(i, j)$, \dots , $g_{N-1}(i, j)$ with the multiplying circuits $M_0, M_1, M_2, \dots, M_{N-1}$ and thereafter adds these coefficients with the adding circuit 63 and thereby generates and outputs the compensation coefficient $g(i, j)$ of 1. In this case, the weighting coefficients $w_0, w_1, w_2, \dots, w_{N-1}$ in the multiplying circuits $M_0, M_1, M_2, \dots, M_{N-1}$ are previously set to satisfy the relationship of formula (11).

According to the structure of Fig. 11, the effect similar to that of the fourth embodiment can also be obtained even by generating, after generation of the compensation coefficient from the low frequency element of a plurality of systems, the compensation coefficient of 1.

(6) Other Embodiments

In above embodiments, the compensation coefficient has basically been generated depending on the characteristics explained above with reference to Fig. 4, but the present invention is never limited thereto. The compensation coefficient may be generated depending on various input/output characteristics. For example, it is also possible to use the level converting function based on the input/output characteristics in which the output level is reduced in the course of increase of input level as illustrated in Fig. 12.

Namely, in the method of related art, when such function is used, a pseudo contour is generated in some cases in the image as the result of process because this function is not the function resulting in monotonous increase. However, when the domain is divided for processing by the low-pass filter as in the cases of the embodiments explained above, a large change of pixel value resulting in inverted relationship of the small and large pixel values can be prevented in the neighboring domains having the value of pixel value depending on the passing frequency bandwidth of the low-pass filter. Therefore, generation of pseudo contour can be avoided effectively.

In above embodiments, the coefficient calculating function G is generated by the arithmetic process of the formula (6) using the level converting function, but the present invention is never limited thereto and it is also possible that the coefficient calculating function G is freely set without use of the level converting function T.

In addition, in the embodiments explained above, after the gradation is compensated by the gradation compensating circuit, the dynamic range is then suppressed by the subsequent signal processing circuits. But the present invention is not limited thereto and it is also possible to execute these processes at a time by setting the corresponding coefficient calculating function G.

Namely, since it is requested in the process to suppress the dynamic range that the number of bits of pixel value output

from the number of bits of the input pixel value is rather small, the maximum value of the output level is set to the allowable maximum value of the output image in the level converting function T and the coefficient calculating function G is generated using such maximum value. Thereby, these processes can be executed at a time.

Moreover, when the coefficient calculating function G is set freely without use of the level converting function T, it is enough to set the coefficient calculating function G to satisfy the following formula. Here, l indicates an input pixel level; L_{\max} , the maximum value of input pixel level and $L0_{\max}$, the maximum value of the output pixel level.

$$l \times G(l) \leq L0_{\max}$$

$$0 \leq l \leq L_{\max} \quad \cdots (12)$$

Moreover, in above embodiments, the quantizing circuit, look-up table and interpolating circuit are used in the second and third embodiments, but the present invention is not limited thereto. Namely, all or any one of the quantizing circuit, look-up table and interpolating circuit may also be adapted to the embodiments other than the second and third embodiments.

On the contrary, the quantizing circuit may be avoided as required in the second and third embodiments.

Moreover, in above embodiments, the luminance signal is generated from a color signal and gradation of color signal is compensated with reference to this luminance signal.

However, the present invention is not limited thereto. The present invention can widely be adapted, for example, on the occasion of processing the image sensing result (Fig. 14) in which the amplitude-modulated color signal is superimposed on the luminance signal output from a single plate type solid-state image sensing device through the setting of the color filter illustrated in Fig. 13, or when the video signal consisting of the luminance signal and color difference signal is processed or when the synthetic video signal in which the chroma signal is superimposed on the luminance signal is processed.

For example, when the image sensing result in which the amplitude-modulated color signal is superimposed on the luminance signal is processed, color noise can effectively be avoided to compensate for the gradation by setting resolution of the compensation coefficient lower than the modulation frequency of the color signal.

In addition, when the video signal consisting of the luminance signal and color difference signal is processed, the compensation coefficient is calculated based on the luminance signal and the gradation of the luminance signal and color difference signal is compensated depending on such compensation coefficient. Thereby, the gradation of the video signal of this type can be compensated accurately.

Moreover, in above embodiments, the domain to which the input image data belongs is judged by a low-pass filter and the low frequency element output from this low-pass filter

is used as the result of judgment. However, the present invention is not limited thereto. The effect similar to that of the embodiments explained above can also be obtained by dividing the domain of the processing object image with various processing methods, for example, in such a case that similarity between the freely selected pixels and neighboring pixels around such selected pixels in the processing object image is detected as the characteristic amount, the domain is sequentially expanded from such pixels and such processing object image domain is further divided and the characteristic amount of such domains is used as the result of judgment.

Moreover, in above embodiments, the present invention is adapted to the television camera, but the present invention is not limited thereto. Namely, the present invention can widely be adapted to various image processors such as television receiver, video tape recorder and printer or the like.

According to the present invention, the domain to which the input image data belongs is judged, for example, with reference to the low frequency element of pixel value and the signal level of image data is compensated based on the result of judgment. Thereby, drop of partial contrast can effectively be avoided and gradation can also be compensated.

WHAT IS CLAIMED IS:

1. An image processor for compensating gradation of image data, comprising:

domain judging means for judging a domain to which said image data belongs in order to output the result of judgment;

coefficient calculating means for outputting a compensation coefficient to compensate a pixel value of said image data based on said result of judgment; and

compensating means for compensating a pixel value of said image data depending on said compensation coefficient.

2. An image processor as claimed in claim 1, wherein said domain judging means outputs said result of judgment by detecting a characteristic amount indicating the characteristic of the predetermined range in the vicinity of said image data and said coefficient calculating means outputs said compensation coefficient corresponding to said characteristic amount.

3. An image processor as claimed in claim 1, wherein said domain judging means is a low-pass filter for extracting the low frequency element of said image data and said coefficient calculating means generates said compensation coefficient corresponding to said low frequency element.

4. An image processor as claimed in claim 1, wherein said domain judging means includes quantizing means for quantizing said image data and a low-pass filter for extracting a low frequency element than the image data quantized by said quantizing means, and said coefficient

calculating means generates said compensation coefficient corresponding to said low frequency element.

5. An image processor as claimed in claim 1, wherein said domain judging means includes a plurality of low-pass filters respectively extracting low frequency elements of said image data and signal combining means for generating a combining signal of 1 based on the low frequency element output from a plurality of said low-pass filters and said coefficient calculating means generates said compensation coefficient based on said combining signal.

6. An image processor as claimed in claim 5, wherein said signal combining means generates said combining signal using a weighted mean of low frequency elements output from a plurality of said low-pass filters.

7. An image processor as claimed in claim 5, wherein said signal combining means generates said combining signal through weighted addition of the low frequency elements output from a plurality of said low-pass filters using the preset weighting coefficient.

8. An image processor as claimed in claim 1, wherein said domain judging means includes a plurality of low-pass filters respectively for extracting the low frequency element of said image data and said coefficient calculating means includes a partial coefficient calculating means for respectively generating a compensation coefficient from the low frequency elements output from a plurality of said low-pass filters and coefficient combining means for

generating said compensation coefficient based on said compensation coefficient.

9. An image processor as claimed in claim 8, wherein said coefficient combining means generates said compensation coefficient with a weighted mean of said compensation coefficients.

10. An image processor as claimed in claim 8, wherein said coefficient combining means generates said compensation coefficient by weighted addition of said compensation coefficients corresponding to the preset weighted coefficient.

11. An image processor as claimed in claim 1, wherein said compensating means compensates for pixel value of said image data by multiplying said compensation coefficient with the pixel value of said image data.

12. An image processor as claimed in claim 1, wherein the number of bits of image data output from said compensating means is reduced in comparison with the number of bits of the input image data.

13. An image processor as claimed in claim 1, wherein said image data has been obtained by sampling, with the predetermined frequency, the signal in which the amplitude-modulated color signal is superimposed sequentially to the luminance signal.

14. An image processor as claimed in claim 1, wherein said image data has been obtained by sampling the color signal with the predetermined frequency.

15. An image processor as claimed in claim 1, wherein said image data has been obtained by sampling the luminance signal and color difference signal with the predetermined frequency.

16. An image processing method for compensating for gradation of image data comprising:

domain judging process to output the result of judgment by judging a domain to which said image data belongs;

coefficient calculating process to output the compensation coefficient for compensating for the pixel value of said image data on the basis of said result of judgment; and

compensating process to compensate for the pixel value of said image data corresponding to said compensation coefficient.

17. An image processing method as claimed in claim 16, wherein said domain judging process outputs said result of judgment by detecting a characteristic amount indicating the characteristic of the predetermined range in the vicinity of said image data and said coefficient calculating process outputs said compensation coefficient corresponding to said characteristic amount.

18. An image processing method as claimed in claim 16, wherein said domain judging process extracts the low frequency element of said image data and said coefficient calculating process generates said compensation coefficient corresponding to said low frequency element.

19. An image processing method as claimed in claim 16, wherein said domain judging process includes a quantizing process to quantize said image data and a process to extract the lower frequency element than the image data quantized by said quantizing process and said coefficient calculating process generates said compensation coefficient corresponding to said low frequency element.

20. An image processing method as claimed in claim 16, wherein said domain judging process includes a low frequency element extracting process to extract a plurality of low frequency elements of said image data in different frequency bands and a signal combining process to generate a combining signal based on a plurality of said low frequency elements, and said coefficient calculating process generates said compensation coefficient based on said combining signal.

21. An image processing method as claimed in claim 20, wherein said signal combining process generates said combining signal with a weighted mean of a plurality of said low frequency elements.

22. An image processing method as claimed in claim 20, wherein said signal combining process generates said combining signal with weighted addition of a plurality of said low frequency elements using the preset weighting coefficient.

23. An image processing method as claimed in claim 16, wherein said domain judging process extracts a plurality of low frequency elements of said image data in different

frequency bandwidths and said coefficient calculating process includes a partial coefficient calculating process to generate compensation coefficient from a plurality of said low frequency elements and a coefficient combining process to generate said compensation coefficient based on said compensation coefficient.

24. An image processing method as claimed in claim 23, wherein said coefficient combining process generates said compensation coefficient with a weighted mean of said compensation coefficients.

25. An image processing method as claimed in claim 23, wherein said coefficient combining process generates said compensation coefficient with the weighted addition of said compensation coefficients using a preset weighting coefficient.

26. An image processing method as claimed in claim 16, wherein said compensating process compensates for the pixel value of said image data by multiplying said compensation coefficient with the pixel value of said image data.

27. An image processing method as claimed in claim 16, wherein the number of bits of image data obtained by said compensating process is reduced in comparison with the number of input bits.

28. An image processing method as claimed in claim 16, wherein said image data has been obtained by sampling, with the predetermined frequency, the signal in which the amplitude-modulated color signal is sequentially

superimposed on the luminance signal.

29. An image processing method as claimed in claim 16, wherein said image data has been obtained by sampling the color signal with the predetermined frequency.

30. An image processing method as claimed in claim 16, wherein said image data has been obtained by sampling the luminance signal and color difference signal with the predetermined frequency.

ABSTRACT

The present invention relates to an image processor and an image processing method for compensating gradation by effectively avoiding drop of partial contrast through application to an image processor such as television receiver, video tape recorder, television camera and printer or the like. A domain to which an input image data belongs is judged, for example, with reference to the low frequency element $r(i, j)$ of the pixel value $x(i, j)$ and the signal level $x(i, j)$ of the image data forming an input image VT is compensated on the basis of the result of judgment $r(i, j)$.

16.

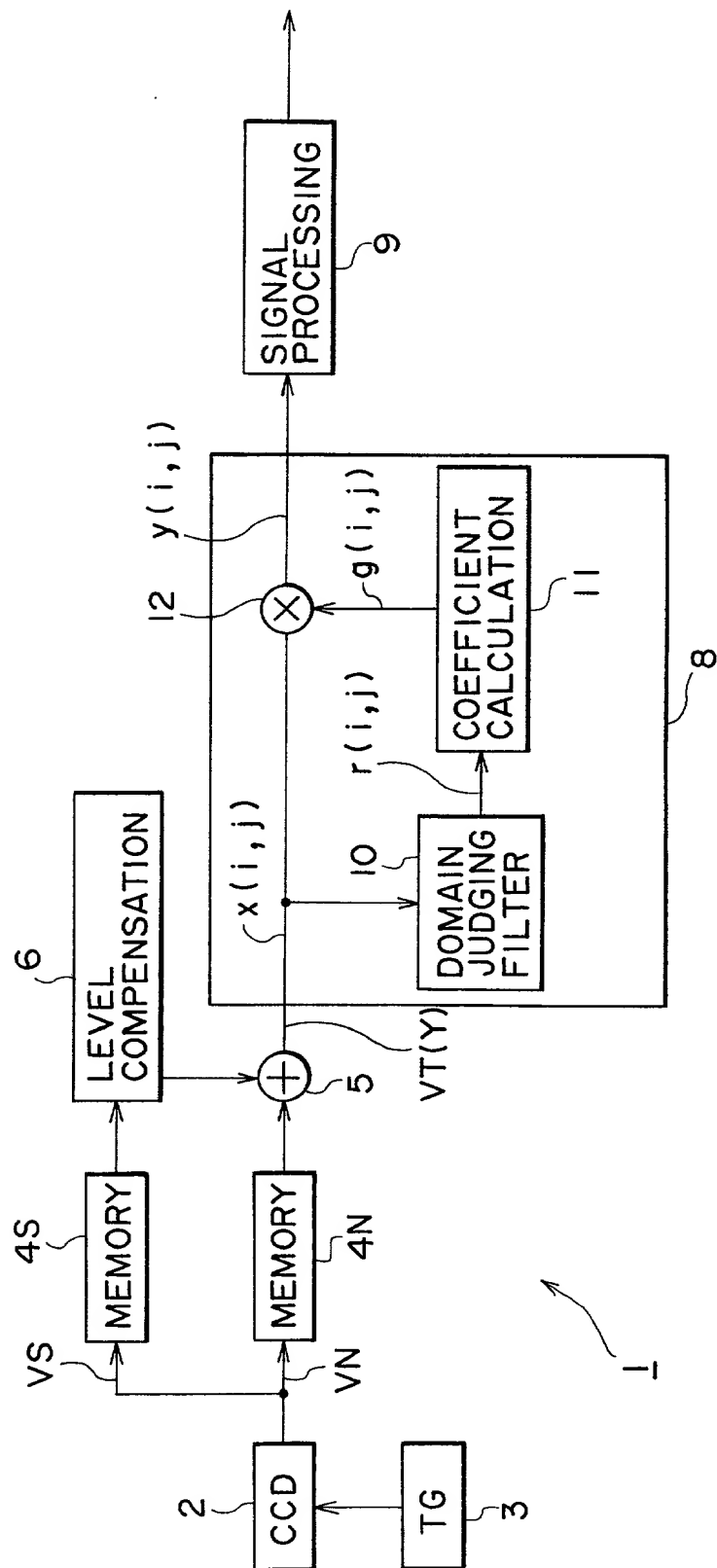


FIG. 2A

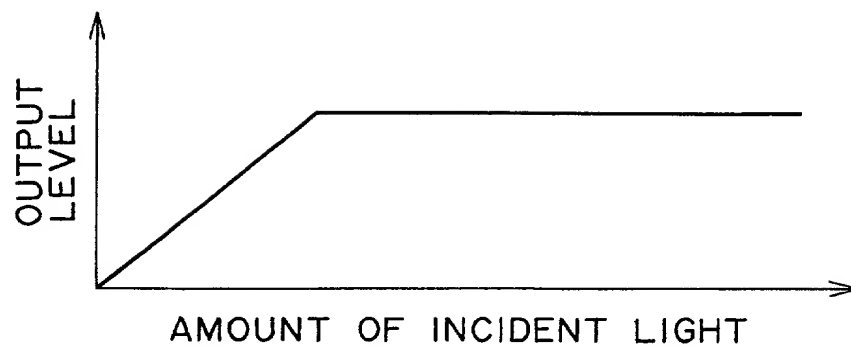


FIG. 2B

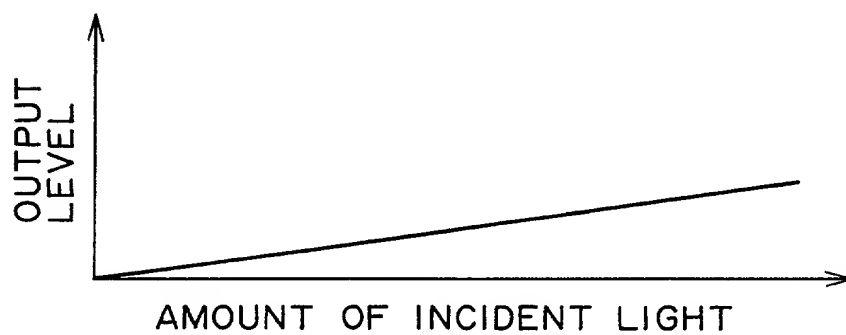


FIG. 2C

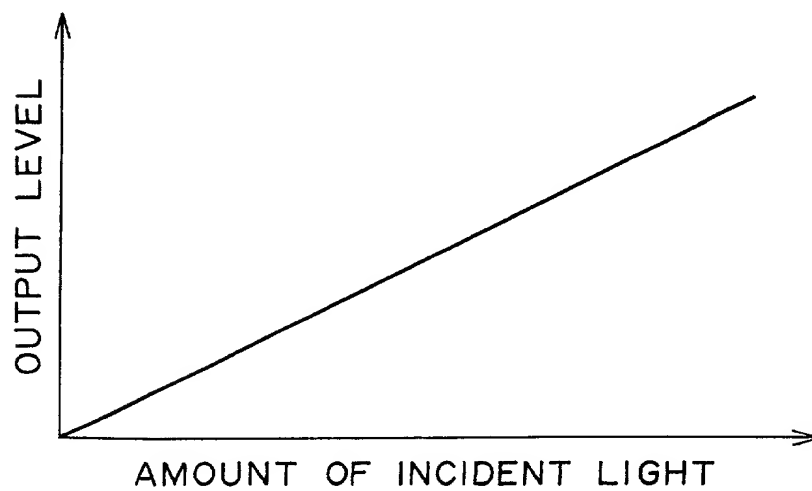


FIG. 3

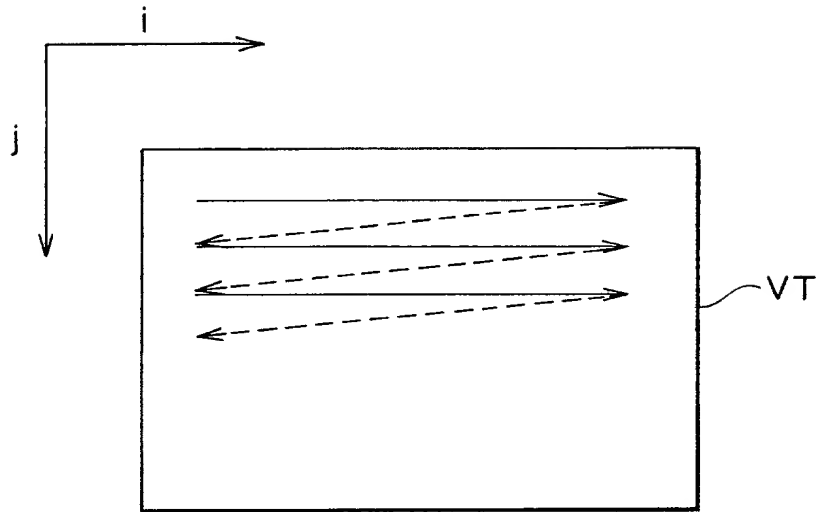


FIG. 4

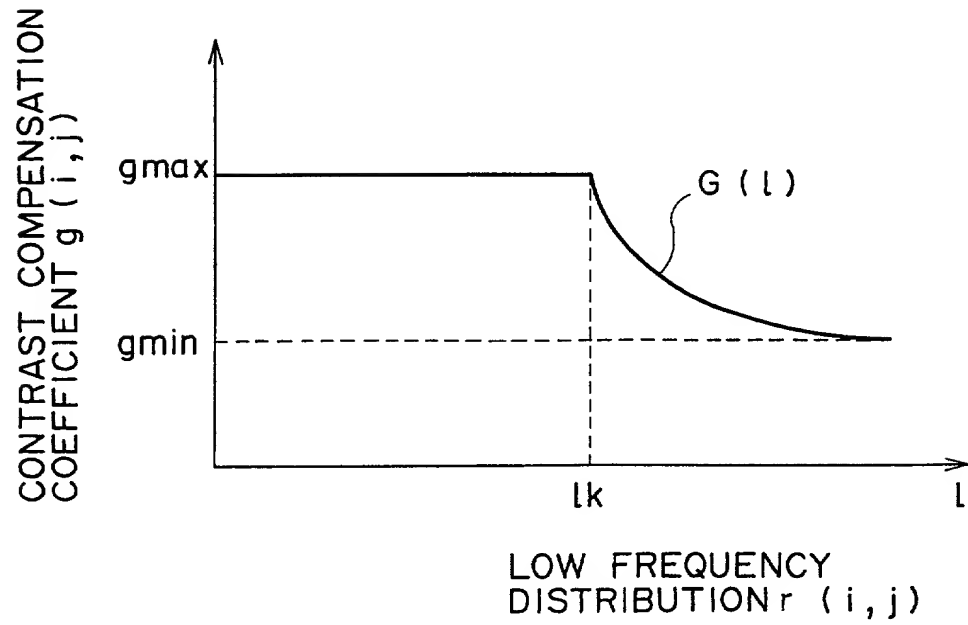


FIG. 5A

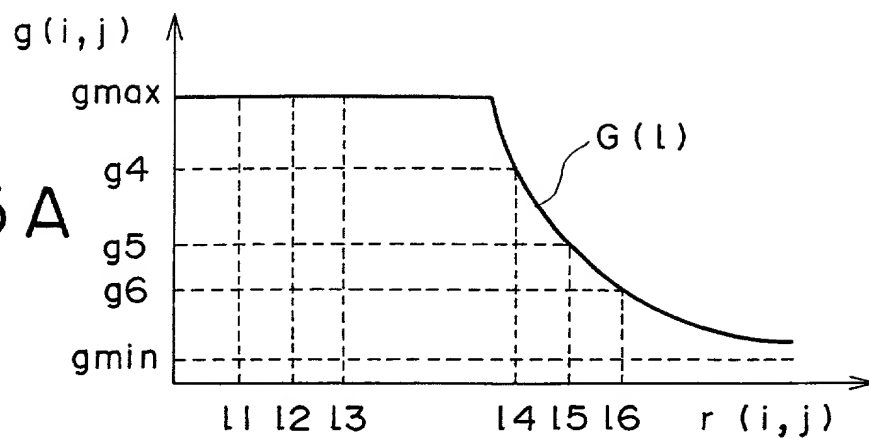


FIG. 5B

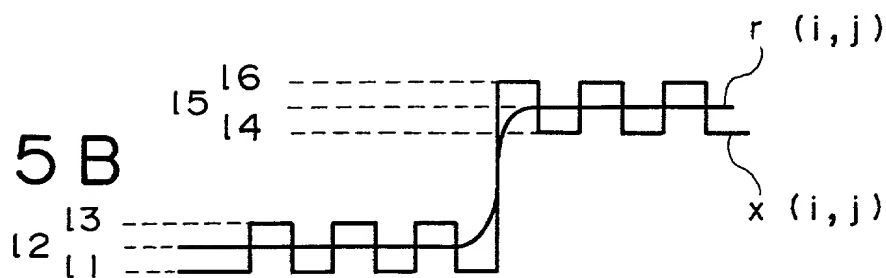


FIG. 5C

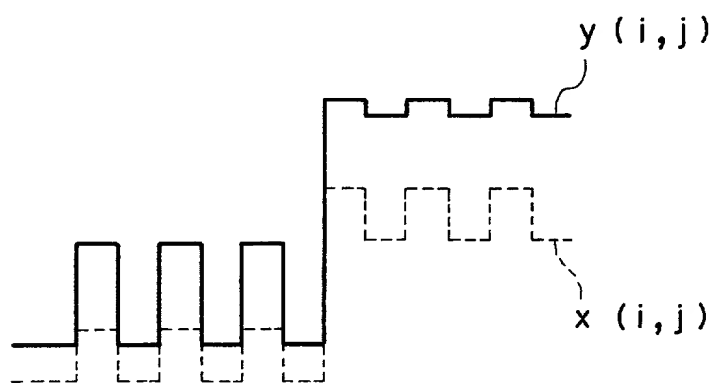
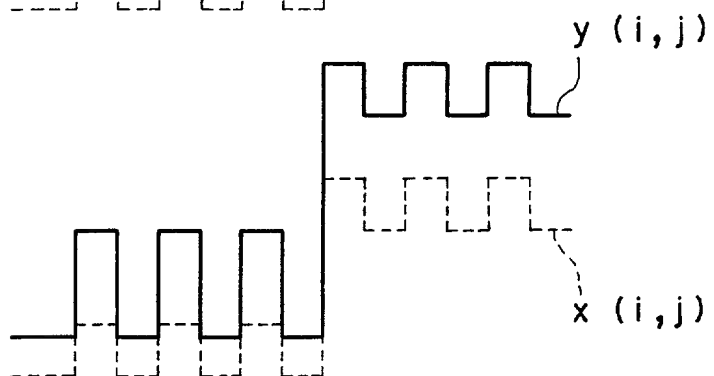


FIG. 5D



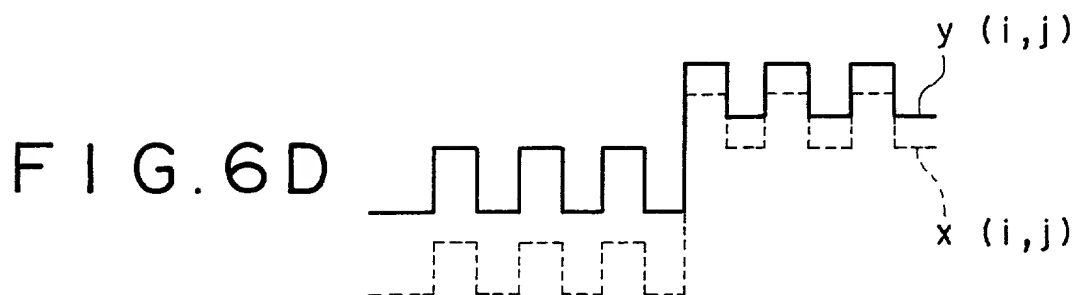
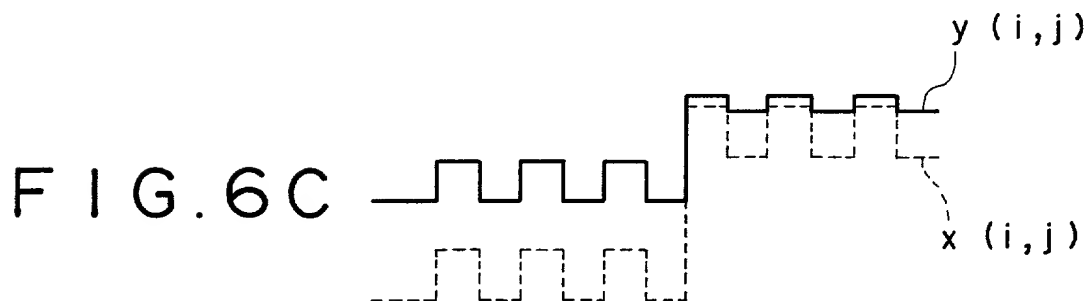
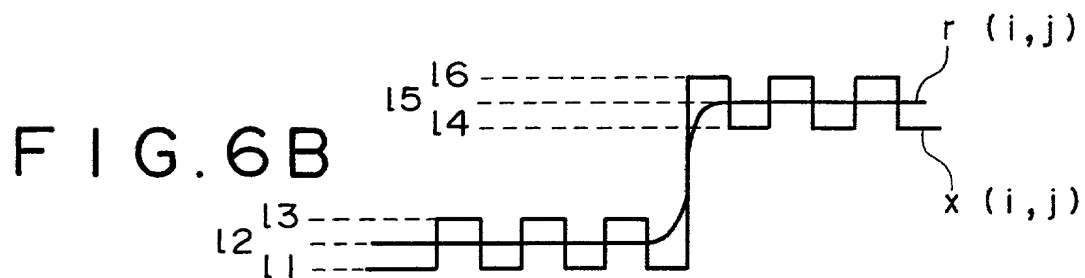
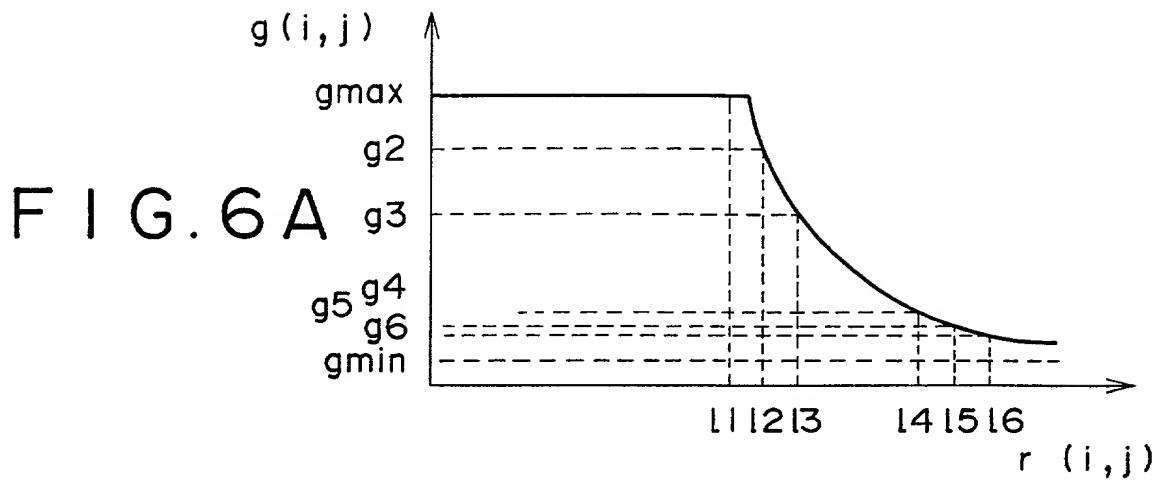


FIG. 7

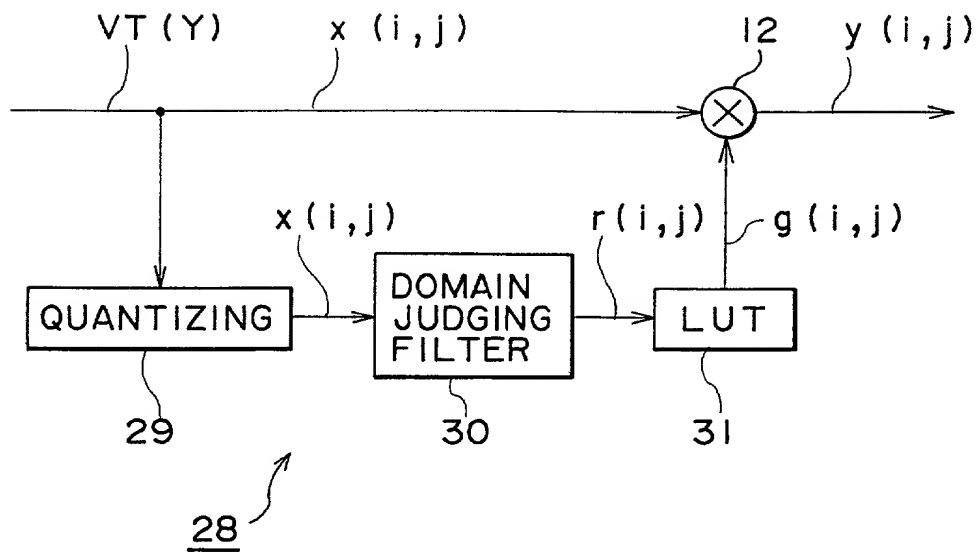


FIG. 8

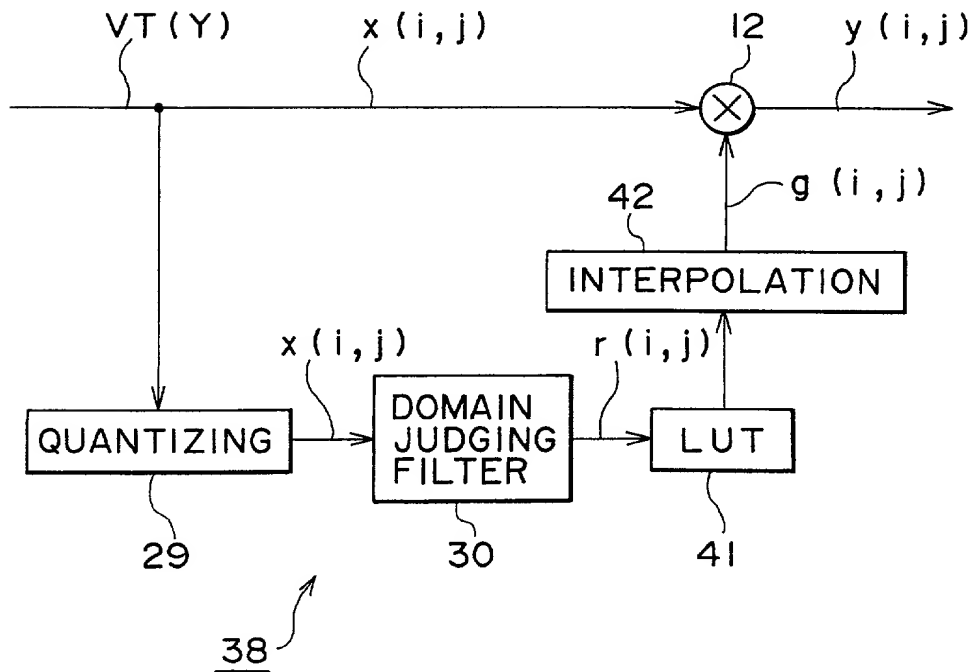
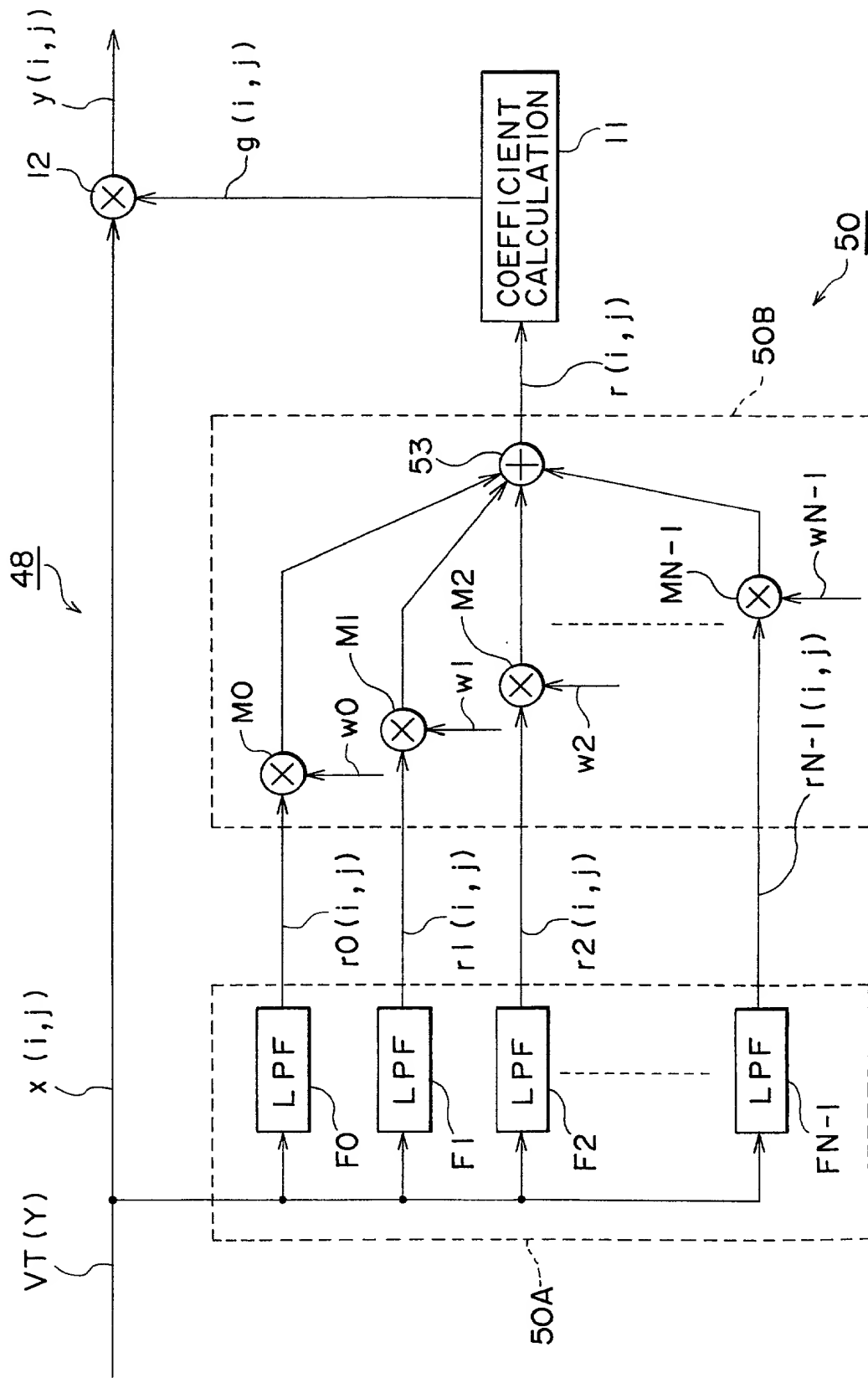


FIG. 9



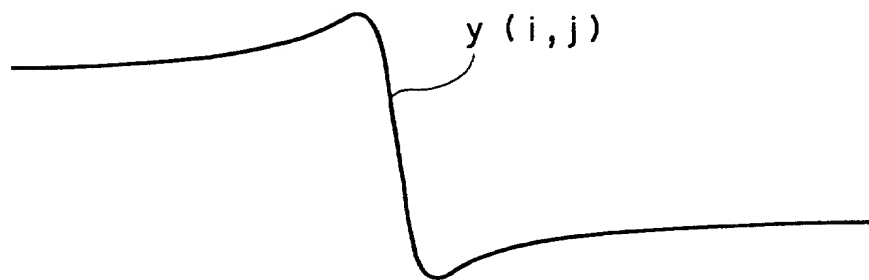
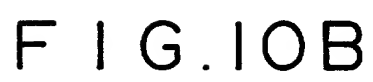
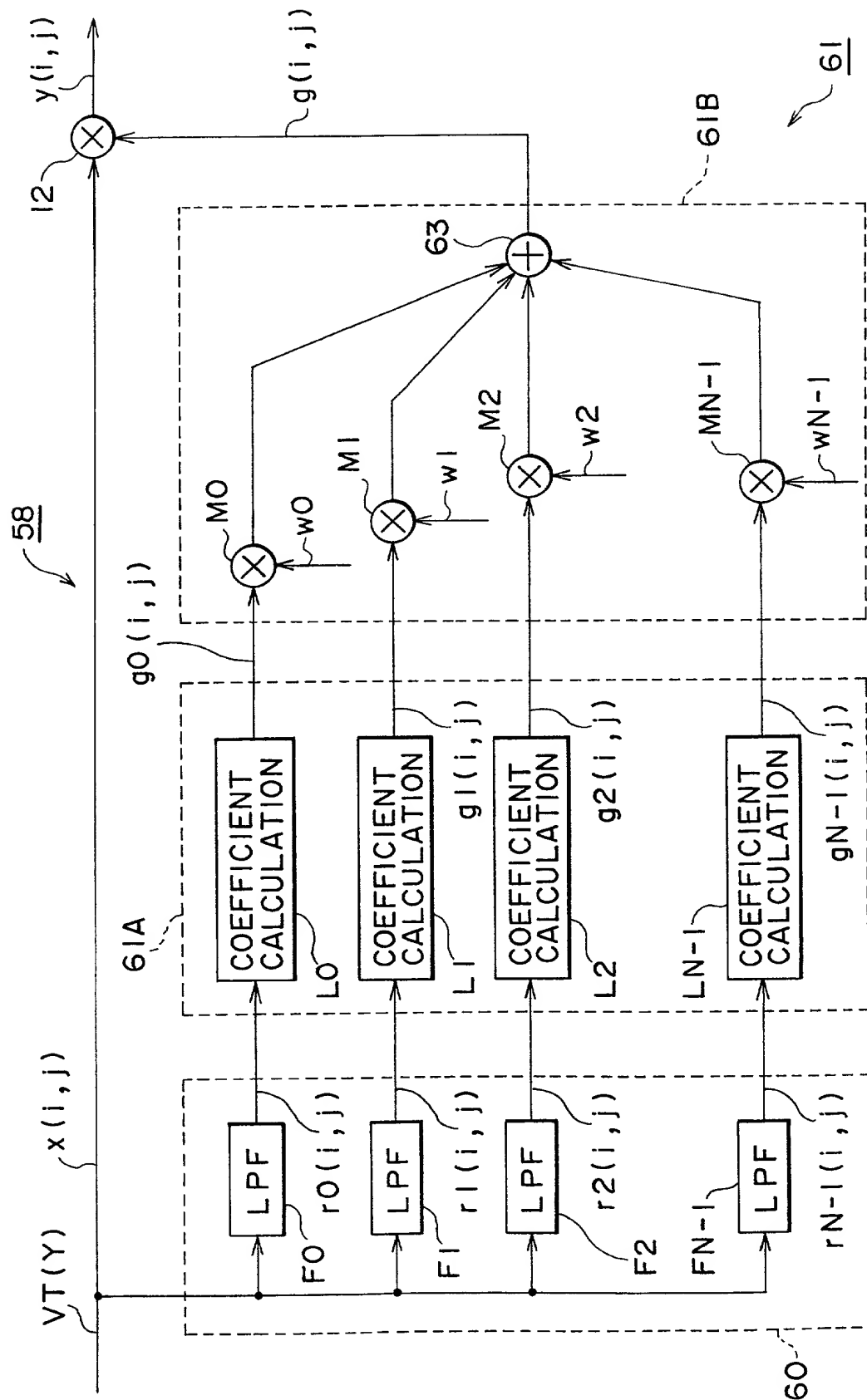
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FIG. 11



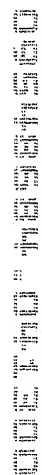
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FIG.14

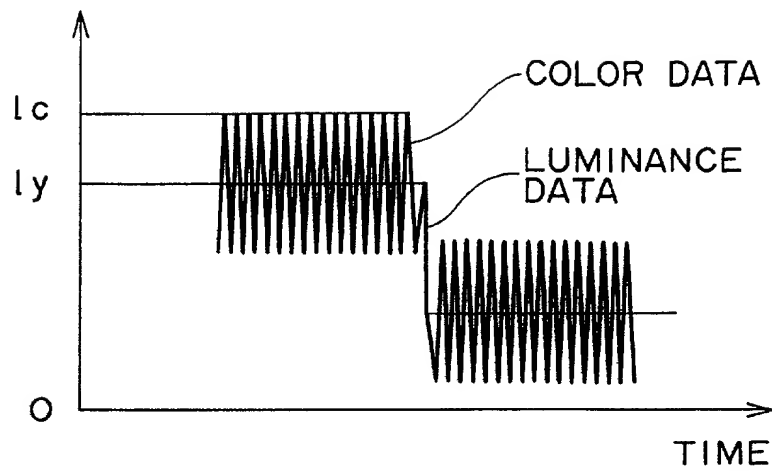


FIG.15

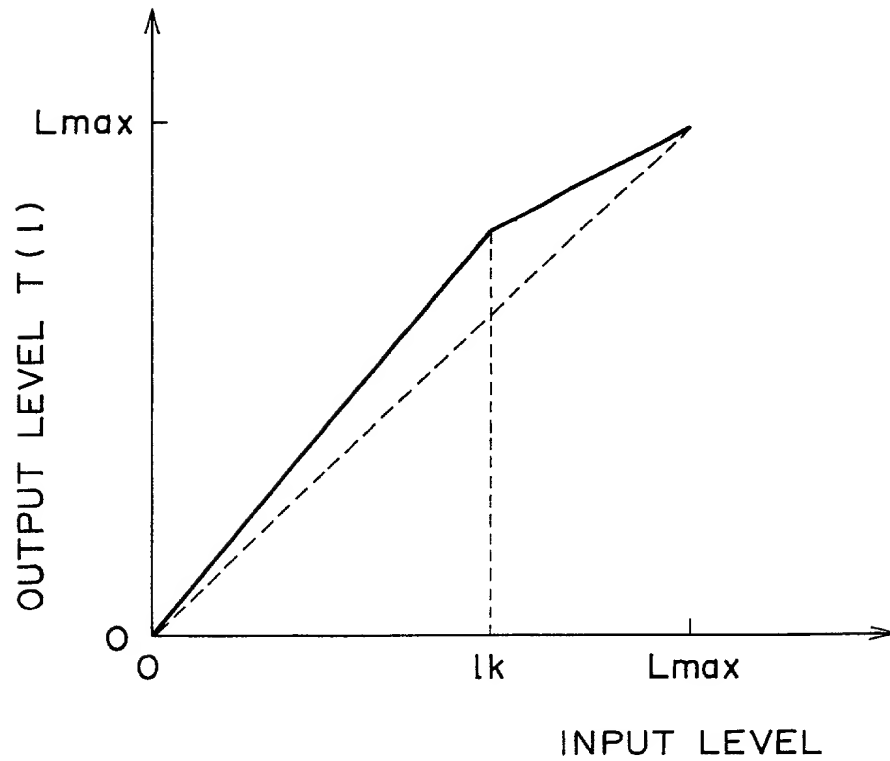


FIG. 16

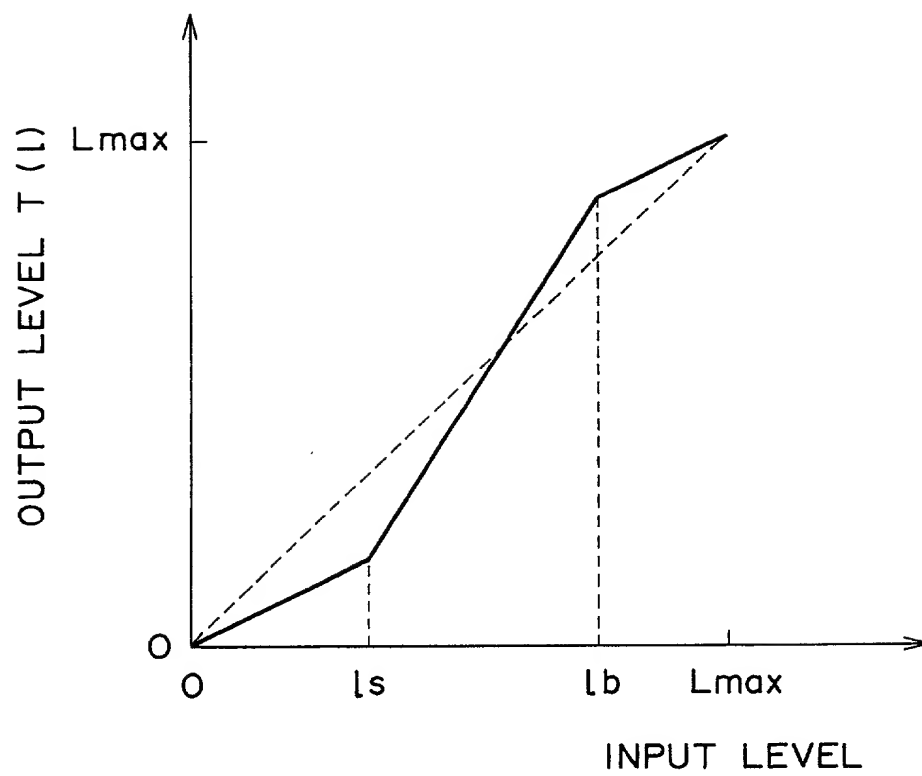
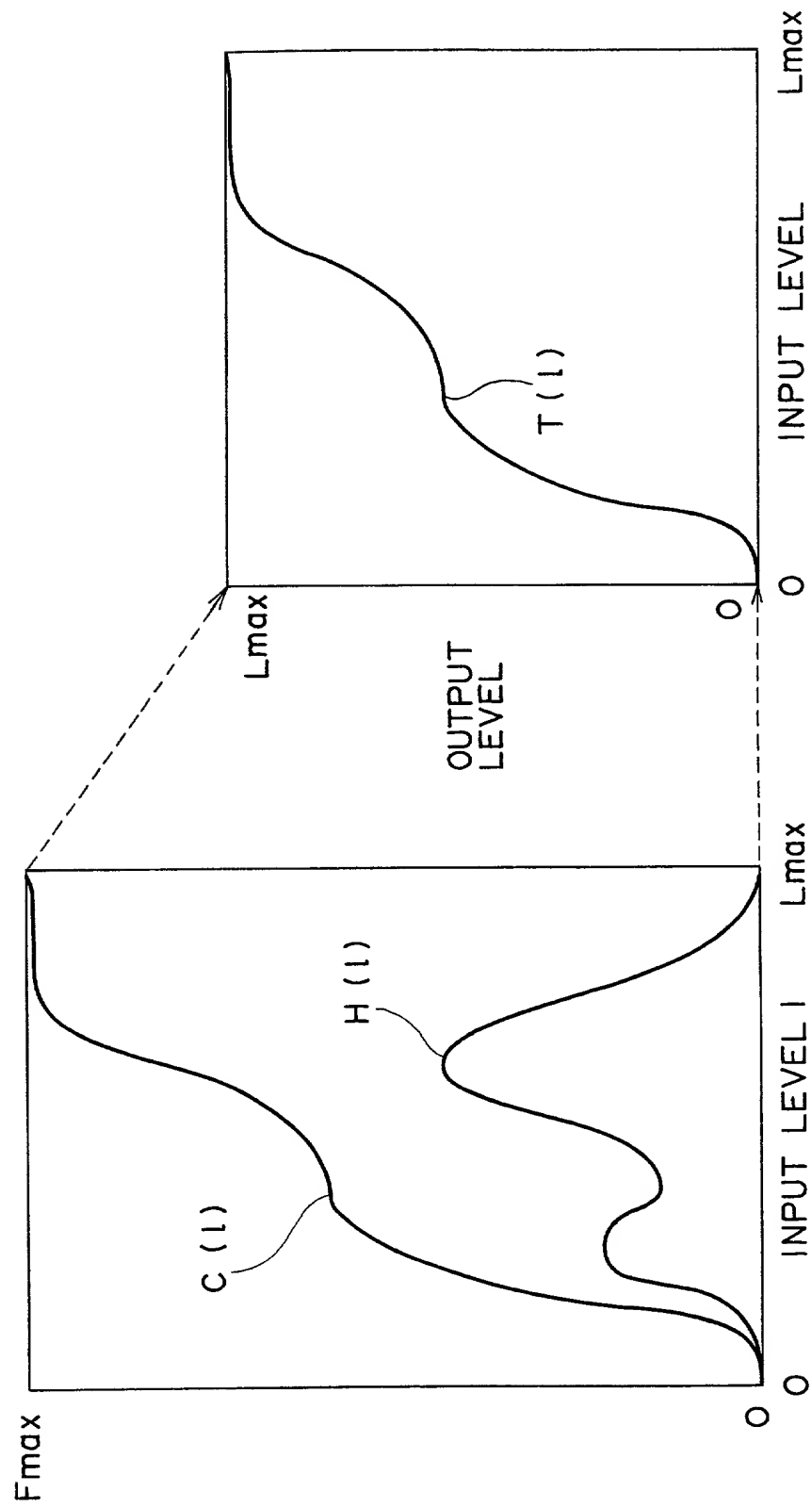


FIG. 17



Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。	As a below named inventor, I hereby declare that:
私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。	My residence, post office address and citizenship are as stated next to my name.
下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。	I believe I am the original, first and sole inventor (if only one named is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled. IMAGE PROCESSOR AND IMAGE PROCESSING METHOD
上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、 <input type="checkbox"/> 月 日に提出され、米国出願番号または特許協定条約国際出願番号を _____ とし、 （該当する場合） _____ に訂正されました。	the specification of which is attached hereto unless the following box is checked: <input type="checkbox"/> was filed on _____ as United States Application Number or PCT International Application Number _____ and was amended on _____ (if applicable).
私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。	I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
私は、連邦規則法典第37編第1条56項に定義されたとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。	I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.
私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基き下記の、米国以外の国の少なくとも一カ国を指定している特許協力条約365(a)項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。	I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.
Prior Foreign Application(s) 外国での先行出願 P11-109172 (Number) (番号)	Priority Not Claimed 優先権主張なし 16 April 1999 (Day/Month/Year Filed) (出願年月日)
Japan (Country) (国名)	

Japanese Language Declaration

日本語宣言書

(Number) _____ (番号) _____		(Country) _____ (国名) _____		(Day/Month/Year Filed) _____ (出願年月日) _____	
私は、第35編米国法典119条(e)項に基いて下記の米 国特許出願規定に記載された権利をここに主張いたします。		I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.			
(Application No.) _____ (出願番号) _____		(Filing Date) _____ (出願日) _____		(Application No.) _____ (出願番号) _____	
(Filing Date) _____ (出願日) _____		(Filing Date) _____ (出願日) _____			
私は、下記の米国法典第35編120条に基いて下記の米 国特許出願に記載された権利、又は米国を指定している特許 協力条約365条(c)に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条 第1項又は特許協力条約で規定された方法で先行する米国特 許出願に開示されていない限り、その先行米国出願書提出日 以降で本出願書の日本国内または特許協力条約国際提出日ま での期間中に入手された、連邦規則法典第37編1条56項 で定義された特許資格の有無に関する重要な情報について開 示義務があることを認識しています。		I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.			
(Application No.) _____ (出願番号) _____		(Filing Date) _____ (出願日) _____		(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)	
(Application No.) _____ (出願番号) _____		(Filing Date) _____ (出願日) _____		(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)	
私は、私自身の知識に基づいて本宣言書中で私が行なう表 明が真実であり、かつ私の入手した情報と私の信じることに 基づく表明が全て真実であると信じていること、さらに故 意になされた虚偽の表明及びそれと同等の行為は米国法典第 18編第1001条に基づき、罰金または拘禁、もしくはそ の両方により処罰されること、そしてそのような故意による 虚偽の声明を行なえば、出願した、又は既に許可された特許 の有効性が失われることを認識し、よってここに上記のごと く宣誓を致します。		I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may be jeopardize the validity of the application or any patent issued thereon.			

Japanese Language Declaration

日本語宣言書

委任状： 私は下記の発明者として、本出願に関する一切の
手続きを米特許商標局に対して遂行する弁理士または代理人
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